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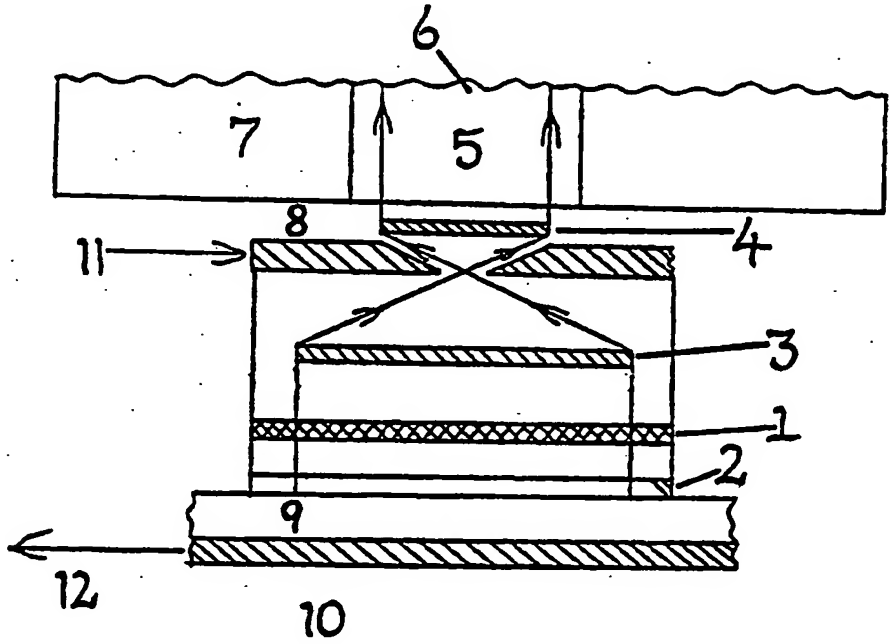
(54) Title: A DIODE LASER SYSTEM EMITTING A HIGH QUALITY LASER BEAM OF CIRCULAR CROSS-SECTION PERPENDICULAR TO THE MOUNTING BASE



(57) Abstract

A laser oscillator system comprising a laser diode (1) which emits light perpendicular to substrate (9) through a small aperture in the upper electrode (8). A micro-lens (3) is etched into the laser diode structure and co-operates with micro-lens (4) to direct the laser output (5) through electrode (8) and into a single mode optical fibre (7). The system allows the generation of circular cross-sectional laser beams (5) of uniform intensity distribution and is scalable to produce a phased locked fibre bundle laser oscillator.

* See back of page

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A DIODE LASER SYSTEM EMITTING A HIGH QUALITY LASER BEAM OF CIRCULAR CROSS-SECTION PERPENDICULAR TO THE MOUNTING BASE

Field of the Invention

This invention relates to a laser diode-single mode optical fibre hybrid laser oscillator system, said diode emitting its output beam in a direction perpendicular to the surface on which is mounted, the output diameter of the emitted laser beam being comparable to both the active area of the diode, laser gain medium and to the area of the upper contact electrode which has a central hole through which said laser beam emerges from the laser diode structure into the core of the optical fibre which is attached to said diode output face.

The invention allows for the generation of circular cross-sectional laser beams of uniform intensity distribution from arrays of said diode laser beam generators which can be injected with the highest possible efficiency into the cores of single mode optical fibres which have comparable diameters, one of the said diodes within the array of said diodes being coupled to one of the optical fibres in an array of such optical fibres. The invention also allows for the matching of a given diode active medium cross-sectional area to the cross-sectional area of the core of optical fibres using a micro lens telescope.

Summary of Prior Art

Prior art laser diodes whose output laser beams were emitted perpendicular to the surface onto which they were mounted suffered from the fact that the laser gain medium was not uniformly excited due to the non-uniform electrical current flow between the electrodes arising from the edge-effects arising from the laser aperture in the upper electrode structure to allow for the emission of the said, laser beam. Said prior art system could not be effectively coupled into the area of a single mode optical fibre.

The present invention overcomes the defects of prior art systems by positioning the upper electrode around the focus region of a pair of lenses so that only a small pin-hole is required in the said electrode to emit the laser beam whilst also providing uniform current flow across the laser gain medium with no edge effects as was the case in prior art systems. In the present invention, the output of laser diode beam generators can also be effectively and directly coupled to the case of single mode optical

fibres.

Background of the Invention

It has proved difficult to coherently phase-lock arrays of diode lasers, that is, to phase-lock such laser arrays as a whole and not in pockets. On the other hand, diode lasers are extremely efficient as far as the conversion of electrical energy into laser beam energy is concerned. However, my experience with solid state laser development has indicated that by forming diode laser - optical fibre hybrid lasers, one loses only about one per cent operating efficiency with proper matching optics between the said diode lasers and optical fibres. In this way, the heat generating diode lasers can be well spread out whilst the optically polished fibre ends can be bundled together to form a single, optically polished, phase-locked output aperture. This result has led the inventor to develop diode laser - optical fibre hybrid lasers which provide most of the advantages of a phase-locked diode laser array without the problems encountered in their scaling to high power levels.

The phase-locking of diode array - fibre array lasers is simplified by the fact that the diffraction of laser light produced from fibre core to fibre core at the output aperture can proceed via reflection off the output mirror in a relatively simple, straight forward manner.

The invention has great advantages over prior art phase-locked laser diode systems in that it is scaleable to high power levels and by selectively switching the individual diodes in the laser diode array it becomes possible to form a high definition image on the output beam or to selectively activate an optical detector array to act like a computer memory.

Summary of the Invention

It is an object of the invention to provide a diode-fibre hybrid laser which allows for the coherent phase-locking of a scaleable laser diode array and a single, phase-locking output aperture formed by bundling together the optically polished ends of the optical fibres connecting the said diodes in such laser diode arrays together via a single, partially transmitting output mirror.

Another object of the invention is to simplify the task of effectively coupling the output of a laser diode into the core of a single mode optical fibre.

It is an object of the invention to uniformly excite the laser diode laser beam generator by providing an electrode whose cross-sectional area is comparable to that of

the active layer of said laser diode.

Another object of the invention is to provide means of optically switching said laser diode-optical fibre oscillator output by electrically switching said laser diode.

The invention provides for the coherent phase-locking of a scaleable diode laser array by coupling the individual outputs of said diodes via single mode optical fibres, the free ends of which are optically polished and bundled to form a single output face of optical fibre core transmitters which emit a single, phase-locked laser beam. By coherently packing these said fibre end transmitters, and adjusting the phase of the laser beams out of the individual transmitters, it becomes possible to scan the output laser beam both vertically and horizontally.

Brief Description of the Drawings

A better understanding of the invention may be obtained from the following considerations taken in conjunction with the drawings which are not meant to limit the scope of the invention in any way.

Figure 1 shows a schematic layout of the laser beam generating diode with its upper surface covered by the electrode which has a central hole through which the laser beam passes after being focussed by a first micro lens then collimated into the core of a single mode optical fibre using a second micro lens.

Figure 2 shows the laser beam generator with a layered sequence of active media.

Figure 3 shows a schematic layout of the invention with the diode array coupled to a bundle of optical fibres whose output faces are bundled into a single output face, said cores of said optical fibres being matched to the output mirror via a micro lens array which aids the phase-locking process.

Figure 4 shows a schematic layout of a doubled up version of the laser beam generating diode structure of the invention with their silicon chips placed back to back and both laser output beams being coupled to their respective laser cores.

Figure 5 shows a schematic layout of a looped diode-fibre laser hybrid oscillator configuration of the invention.

Detailed Description of the Drawings

In Figure 1, numeral 1 indicates the cross-section of the active medium of the diode laser. Numeral 2 indicates alternating layers of different crystalline structures to form a multi layered mirror which reflects the diode laser wavelength either fully as is the case with the non-output mirror or partially transmitting as is the case with

the output mirror. Numeral 3 indicates a micro lens which is an integral part of the diode structure. In a preferred form micro lens, 3 may be of the Fresnel type and simply etched into the said diode laser structure, using etching techniques well known in the art for etching such micro lenses. Numeral 4 indicates a second micro lens system which recollimates the output laser beam indicated by numeral 5 so that it can be injected, for example, into a suitably optically polished and coated core of a single mode optical fibre indicated by numeral 6. Numeral 7 indicates the cladding for the fibre core 6.

In Figure 1, numeral 8 indicates the upper electrode, relative to the base indicated by numeral 9, on which the said laser diode is mounted. Numeral 10 indicates the base electrode which acts both as an electrical connection and heat sink. If 9 and 10 are positioned relatively to each other as shown in Figure 1, then it follows that base 9 has to be electrically conducting as well as heat conducting. Numeral 11 and 12 indicates the two electrical leads connecting said diodes to their power supplies.

In Figure 2, the configuration of Figure 1 is extended to the configuration of the invention with multiple active media 1 layered above each other parallel to base 9. This allows the laser diode to operate at much higher powers than was the case with prior art laser diodes which emitted their laser beams parallel to the substrate on which they were mounted. When such diode active media were seriesed together, the damage threshold of one medium limited the total power through the series of said media so that no effective increase in the diode laser output power could be achieved in practice by using more than one diode in series.

This invention allows for the coupling of 10,000 individual diodes to 10,000 single mode optical fibres with 3-5 micron core diameters and over 80 micron cladding thickness. In Figure 3, numeral 13 indicates the individual laser diodes in an array of such diodes coupled together via a group of single mode optical fibres indicated by numeral 14. Numeral 15 indicates a closely packed array of the optically polished and coated output end faces of fibre 14. Numeral 16 indicates an array of micro lenses which matches the distribution of the core centers of aperture 15. Numeral 17 indicates a partially transparent output mirror which allows for the phase-locking of the diffracted outputs of the emissions from fibres 14 in array 15, a process which in turn phase-locks the diode array 13. The phase-locked output beam is indicated by numeral 18. Numeral 19 indicates the power supply to drive array 13 whilst numeral 20 indicates the control into which switches supply 19.

Figure 4 indicates laser diode 21 with two output ends both of which are optically

connected to optical fibre ends.

In Figure 5, laser diode 21 is connected to two lengths of single mode optical fibre 14 to produce a looped laser oscillator.

The invention has application in the production of uniform diode laser output beams either from an individual diode laser or form large arrays of such lasers which can be matched to optical fibres, forming diode-fibre hybrid laser oscillators with coherently phase-locked outputs. By appropriately switching the diodes within the array, the outputs of the said laser oscillators, can be beam-steered.

The invention has application in the industrial, medical, defence, communications and computing fields where phase-locked, beam steerable and scaleable laser output beams can be utilized.

I claim,

1. A diode-fibre hybrid phase-locked laser oscillator array system consisting of a diode laser beam generator which emits the generated laser beam perpendicular to the base on which said diode is mounted, the electrical excitation field with said diode being highly uniform formed by an electrode which covers most of the cross-sectional area of said diode but has a central hole to allow the said laser beam generated in said diode to exit into the core of a single mode optical fibre using a micro lens telescope, the diode-laser hybrid laser oscillator being completed by attaching a partially transmitting mirror onto the output end of said fibre.

2. A system as claimed in Claim 1 bundled together so that the output ends of said optical fibres are packed into a single, scaleable aperture which emits a single phase-locked laser beam, the phase-locking of said system being achieved via reflection of portions of the output of a given fibre core being distributed against its neighbours.

3. A system as claimed in Claim 2 where the laser diodes are selectively switched so as to form an optical image on said output laser beam.

4. A system as described in Claim 1 where the diode laser beam generating sections have multiple active layers positioned parallel to each other to produce a laser beam of increased power.

5. A system which places two systems as claimed in Claim 1 back to back to produce a looped diode-fibre hybrid laser.

6. A system which places two systems as claimed in Claim 2 back to back and combines the output aperture of said fibre bundles into an angle, phase-locked, scaleable output aperture.

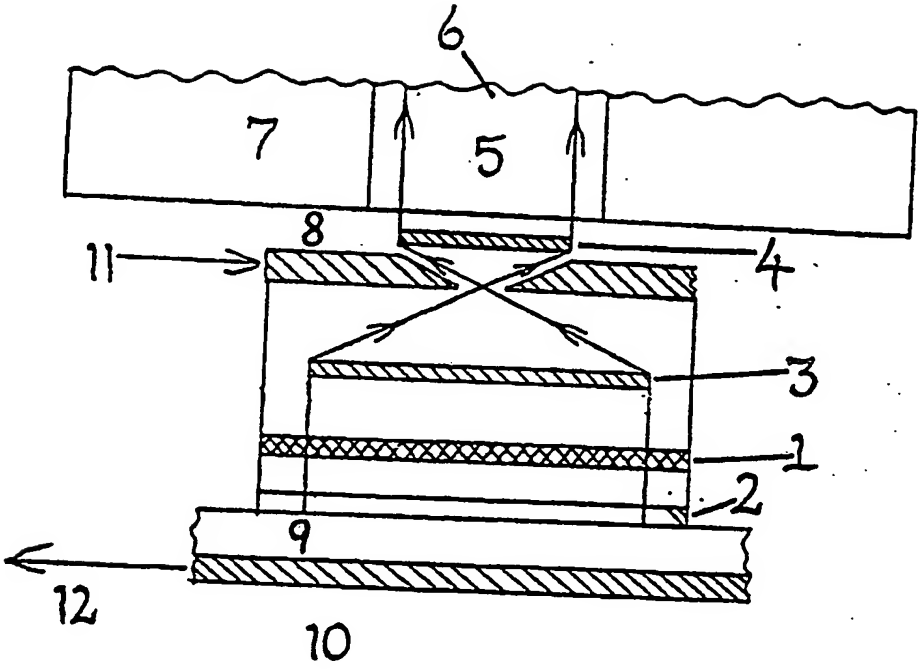

Figure 1

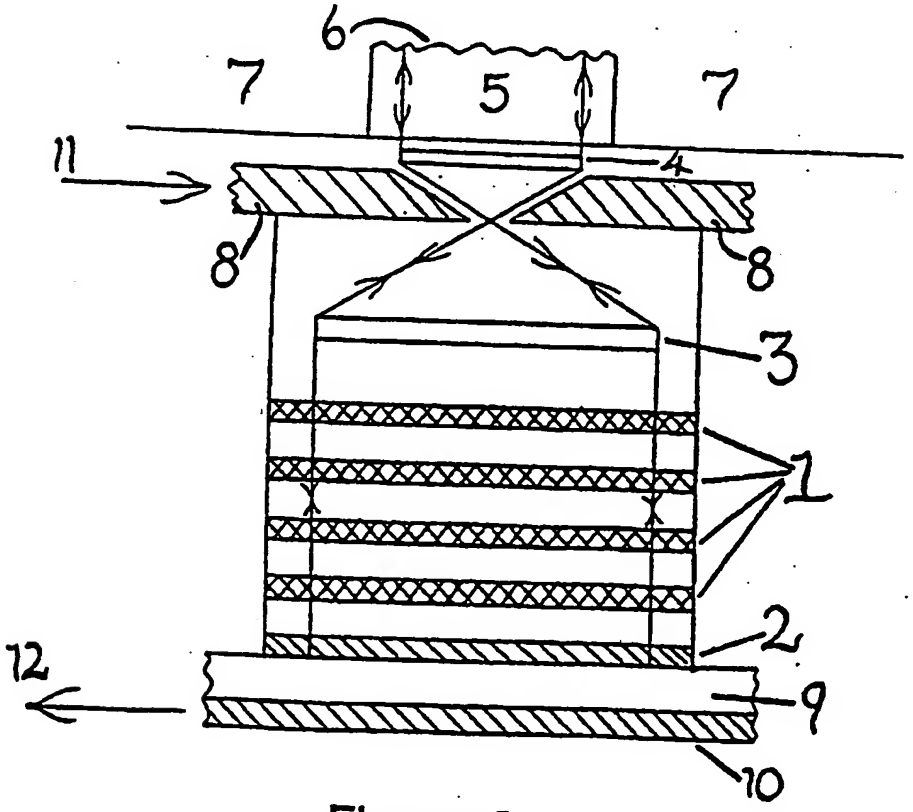

Figure 2

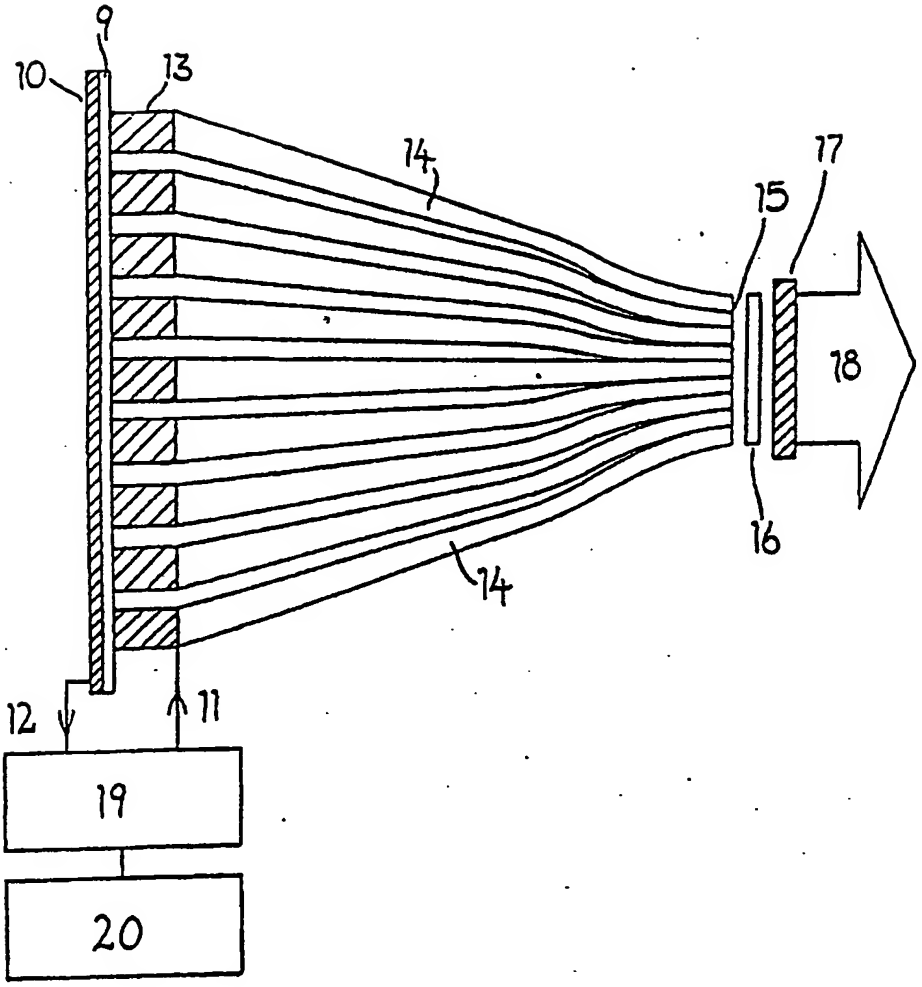

Figure 3

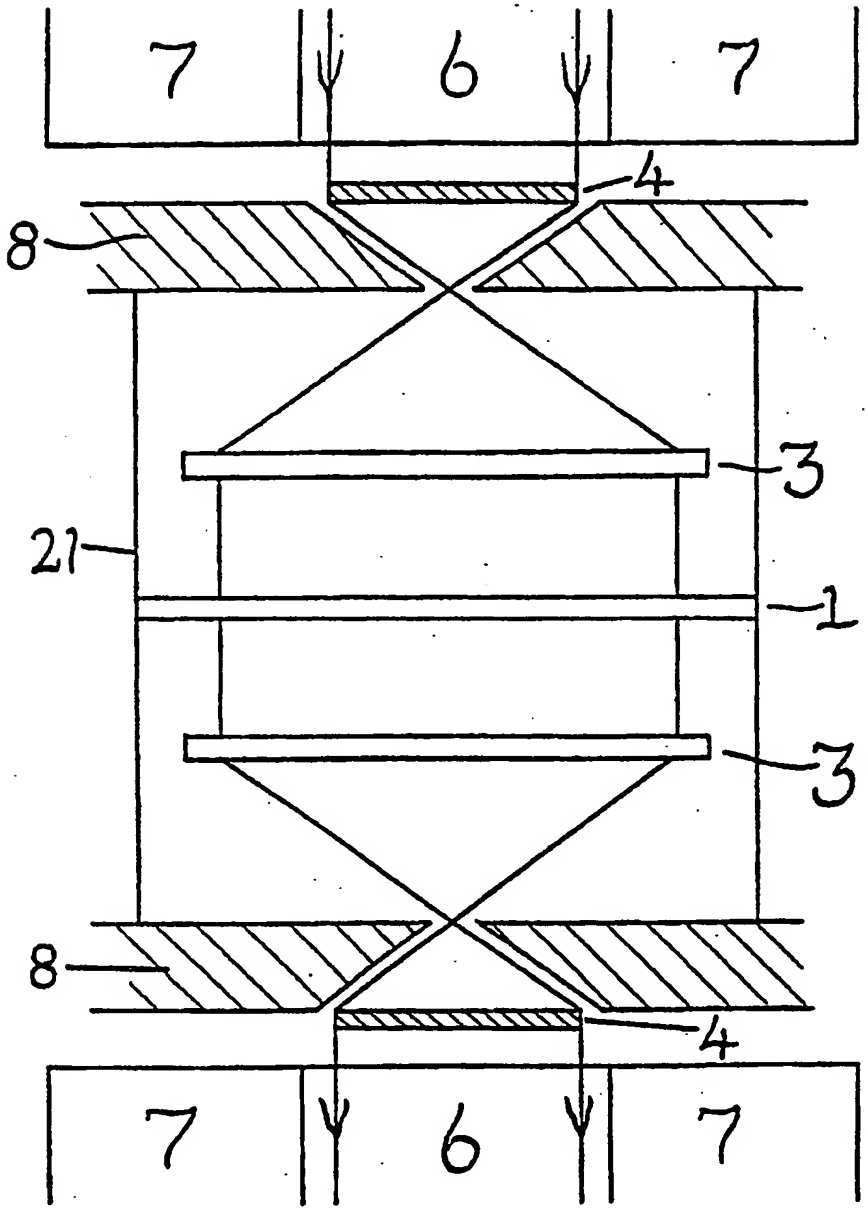

Figure 4

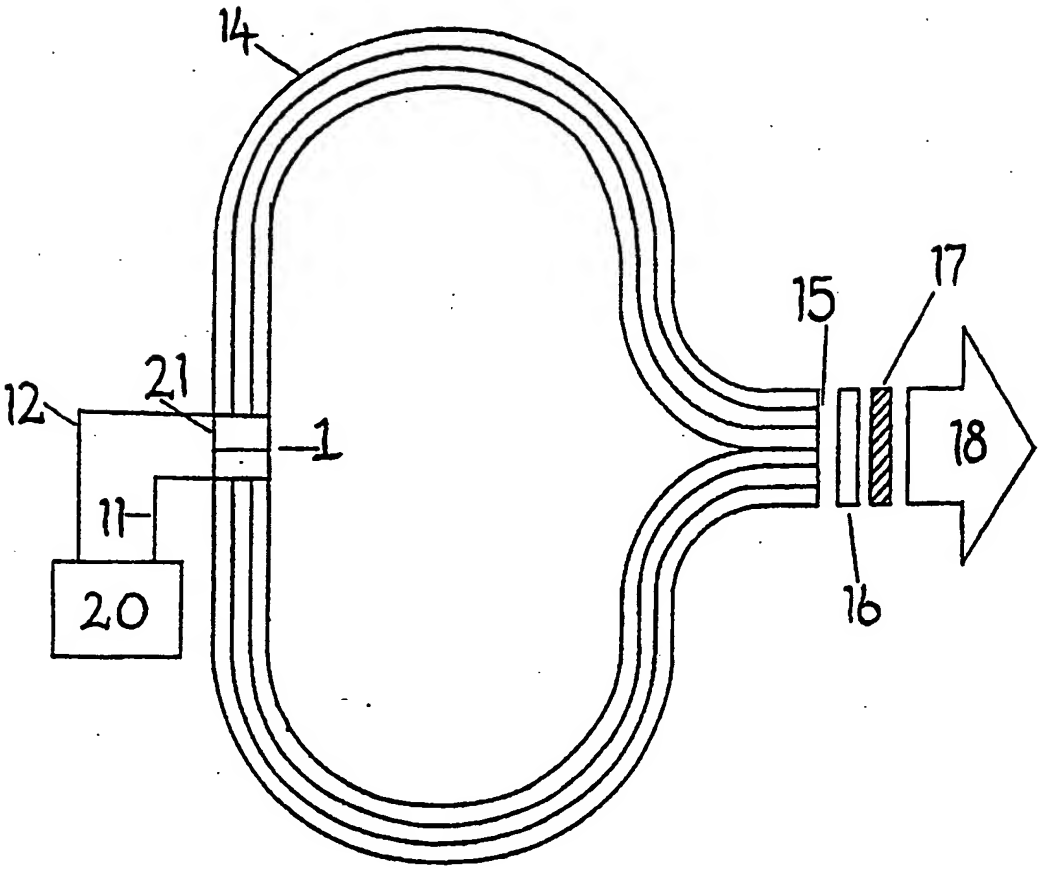

Figure 5

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) 6

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.[5] H01S 3/025, 3/07, 3/085, 3/23, G02B 6/42, H01L 33/00

II. FIELDS SEARCHED

Minimum Documentation Searched 7

Classification System	Classification Symbols
IPC	H01S 3/02 , 3/025, 3/07, G02B 7/26, 6/42

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched 8

AU : IPC as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT 9

Category*	Citation of Document, [11] with indication, where appropriate, of the relevant passages 12	Relevant to Claim No 13
A	EP,A, 143040 (THOMSON - CSF) 29 May 1985 (29.05.85) See particularly fig 1.	
A	WO,A, 82/02957 (MOTOROLA INC.) 2 September 1982 (02.09.82) See particularly pages 2-5.	
A	Patents Abstracts of Japan, P- 186, page 157, JP,A, 58-4102 (NIPPON DENSHIN DENWA KOSHA) 11 January 1983 (11.01.83)	
A	Derwent Abstract Accession no. 89-168730/23, Class V07, JP,A, 1-109313 (HITACHI K.K.) 26 April 1989 (26.04.89)	
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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
26 September 1990 (26.09.90)	12 October 1990
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ANNEX TO THE INTERNATIONAL SEARCH REPORT ON
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Patent Document Cited in Search Report	Patent Family Members		
EP 143040	CA 1245331	DE 3471835	EP 143040
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